COLOR CHANGES AND CHILLING INJURY OF PINK TOMATOES HELD AT VARIOUS TEMPERATURES

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COLOR CHANGES AND CHILLING INJURY OF PINK TOMATOES HELD AT VARIOUS TEMPERATURES

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SUMMARY AND CONCLUSIONS

"Pink" tomatoes of different stages of ripeness were held at several temperatures to simulate normal transit conditions and also to test temperatures considerably lower than those recommended for tomatoes. The purpose was to determine temperatures needed to control ripening and to find out whether short periods at 40° F. would adversely affect subsequent ripening. In addition, tomatoes were held at 32° to insure the development of chilling injury. The color of each fruit was determined by visual inspection, and in some tests the color was also measured by a color and color difference meter (CDM) of the Hunter type.

Simulated transit temperatures of 55° and 50° F. for 4 days provided better control of ripening than 60° for tomatoes whose surfaces were 30 to 50 percent colored at the start of the test. However, 60° was superior to 55° and 50° for tomatoes of 10 to 25 percent color that needed to ripen during transit.

The rate of change in color during the 4-day simulated transit period was directly related to holding temperature and stage of ripeness. The greatest change in color occurred in fruits with the greatest need to ripen.

Pink fruits increased in color very little at 40° F., but if held only a few days, they later ripened satisfactorily at a favorable temperature such as 70°. Chilling injury was not evident in pink tomatoes held at 40° for 6 days. If necessary, pink tomatoes can be shipped at temperatures as low as 40° for 2 to 4 days. However, that temperature is lower than is needed or is recommended.

Fruits held at 32° F. lacked intensity of red when ripened at 70° and were less firm than fruits held at the higher temperatures. Fruits held at 32° for 10 to 14 days developed serious chilling injury, as indicated by the extent of alternaria rot (*Alternaria tenuis* auct.) that developed on apparently wound-free areas when the fruits were shifted to 70°.

Mature-green tomatoes were injured more by low temperature than pink fruits, as indicated by increased alternaria rot on mature-green tomatoes after a 14-day holding period at 32° F.

THE PROBLEM

Each year a part of the tomato crop shipped for fresh use is harvested in the "pink" stage after some yellow or red has developed. Ripening does not progress uniformly in tomatoes on the vines, and fruits of various stages of ripeness are obtained even when the fruits are harvested frequently. Fruits of different stages of ripeness are sorted and packed in similar ranges. They may be shipped separately or all may be included in the same load. Pink tomatoes are at times also shipped in loads of mixed produce. Since these pink, or so-called vine-ripened, tomatoes are more perishable than those harvested mature green, one of the critical problems is to control ripening during transit. Fruits just "turning" color need a moderate temperature to promote gradual ripening, whereas fruits with 50 percent or more of the surface colored need temperatures permitting little additional ripening during transit. If both color ranges are included in the load, a compromise on transit temperature must, of course, be made.

Literature concerning problems of marketing pink tomatoes is not extensive (*1–6*, *9*)[1] and little has been published on the effect of temperature on rate of ripening or on chilling injury.

In studies with glasshouse-grown tomatoes harvested at the turning stage, Tompkins (*10*) in England found that tomatoes are adversely affected by temperatures below 50° F. He reported that the skin of tomatoes became increasingly susceptible to fungal invasion as the temperature was reduced below 50°. The period of holding was also directly related to the extent of decay. For

[1] Italic numbers in parentheses refer to Literature Cited, p. 6.

example, exposure to 32° for 6 days did not increase decay, but exposure for 9 days or more did.

In an earlier study McColloch (*7*) assumed that receivers at terminal markets preferred that pink tomatoes arrive with at least 50 percent but not more than 75 percent of the surface colored. Judging colors visually, McColloch found that tomatoes with 40 to 50 percent of the surface colored when packed had to be cooled rapidly to 50° F. and transported at that temperature in order to hold ripening to the desired color range. However, considerably more latitude in cooling and transit temperatures was found for tomatoes with 10 to 15 percent color when packed.

The purpose of this study was to determine (1) the effect of simulated transit temperatures on the rate of color change and final ripening and (2) whether short periods at relatively low temperatures, such as during transit in mixed loads of vegetables, would cause chilling injury.

EFFECT OF HOLDING TEMPERATURES ON COLOR CHANGES

Materials and Methods

The data in table 1 and figures 1 and 2 were collected from tests in 1961 with Rutgers tomatoes grown at Beltsville, Md. Harvesting was done after the fruits had developed some yellow or red. The tomatoes were washed, graded, and carefully unified in test lots, including three limited color ranges.

The color of each fruit was determined individually, both by a color and color difference meter (CDM) of the Hunter type and by visual inspection. The fruits were wiped with a cloth to remove any surface dirt and moisture. Each fruit was numbered so that color changes during ripening could be followed. Readings were made on six areas of the fruit. The CDM was calibrated, using a white standard with small aperture and large area illumination, to the following values: $L=91.6$, $a_L=-1.9$, and $b_L=2.0$.[2] The CDM data were analyzed according to the Tomato Color Index (T.C.I.) (*11*). The color was determined at the start of the tests, after a 4-day simulated transit period at 50°, 55°, and 60° F., and after final ripening at 70°. There were 20 fruits in each color range at each temperature. Fruit color, judged visually, was expressed in percentage of area colored and intensity of color.

The relationship of the visual color ratings to the T.C.I. values obtained by the CDM for the different color ranges is shown in figure 1.

Because of the large number of measurements to be made, it was necessary to conduct a separate test for each holding temperature. These temperatures and the color range were as follows:

Holding temperature (°F.):	*Color range (percent)*
60	10–15, 15–25, 30–40
55	10–15, 20–30, 35–45
50	10–15, 20–30, 40–50

At each temperature the fruits were held for a 4-day simulated transit period and then ripened at 70°.

[2] L, a_L, and b_L are symbols for the color of a product, where L is the lightness or darkness of the sample, a_L is redness when plus (+) and greenness when minus (−), and b_L is yellowness when plus (+) and blueness when minus (−).

Results

Visual color ratings assigned to each test fruit were averaged for each color range, holding temperature, and period observed, as shown in table 1.

In objective measurements, the T.C.I. values (fig. 2) generally substantiate the subjective determinations (table 1). The principal variance between subjective and objective measurements of color was in the three lots held at 50° F. The CDM registered lower T.C.I. values, indicating less color, than were assigned through visual measurements.

As expected, ripening in all color ranges was slowed as the temperature was reduced from 60° to 50° F. Simulated transit temperatures of 55° and 50° provided better control of ripening than 60° for tomatoes with 30 to 50 percent color at the start of the test. However, a simulated transit temperature of 60° was more satisfactory for tomatoes that needed to ripen (10 to 25 percent color) than 55° or 50°. Although fruits of 20 to 30 percent color had an average rating of 53 and 50 at 55° and 50°, respectively, a rating which meets the lower limits of the desired range arbitrarily established for arrival at market, many fruits had lower color values than the averages. Fruits with only 10 to 15 percent color at the start of the test were restricted too much in ripening at both 55° and 50°.

The rate of change in color during the 4-day simulated transit period was directly related to both holding temperature and degree of ripeness. The greatest change in ripening, as indicated by increase in color, occurred in fruits with the greatest need to ripen (table 1).

In evaluating the final color it was not practical to establish a specific time for the final readings. The purpose of the readings was to establish whether the tomatoes ripened satisfactorily after the simulated transit period. Objective readings after the 70° F. ripening were approximately the same whether measured after a period of 7 or 11 days. Because the readings were not made at the same time, the slope of the curves beyond the 4-day holding period (fig. 2) should not be interpreted as rates of color change for the various lots.

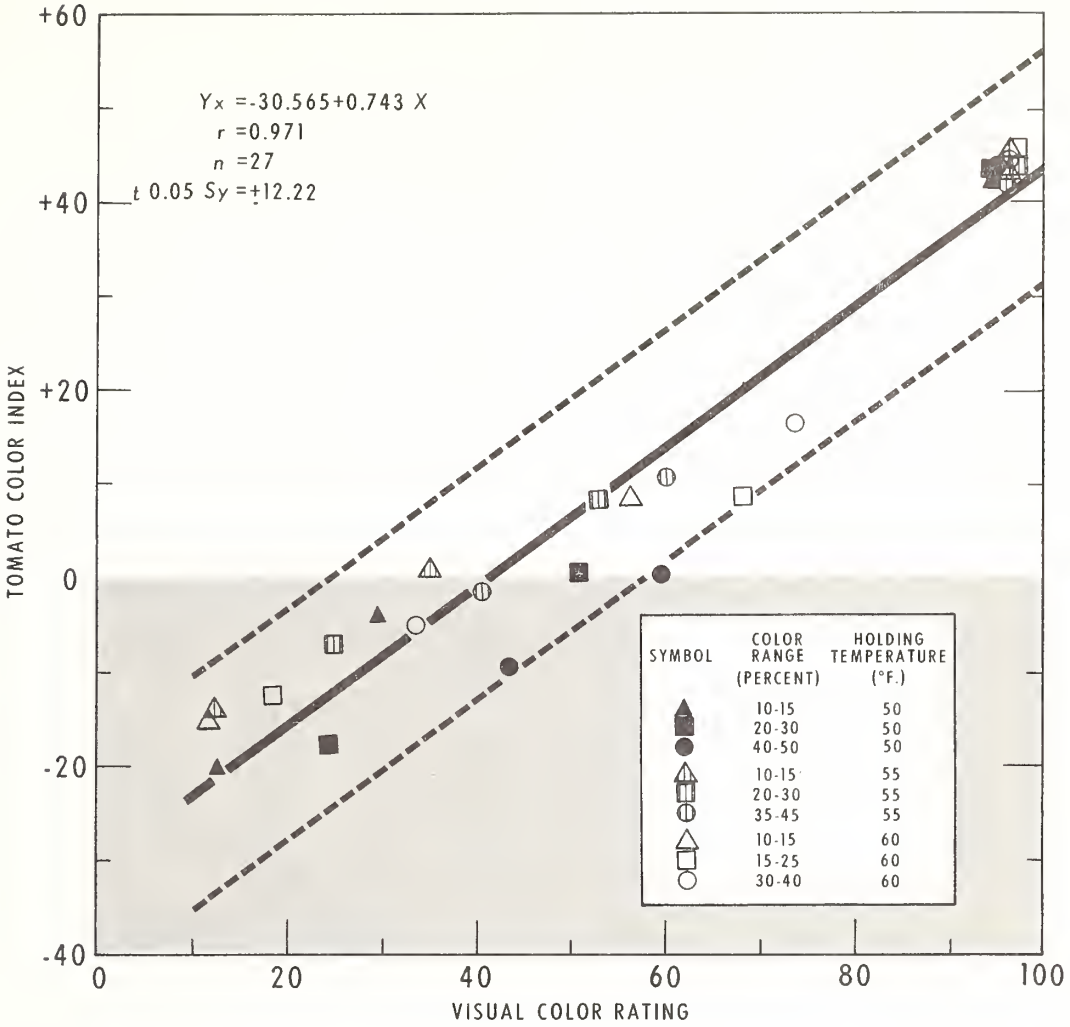

FIGURE 1.—Relationship of visual color rating in percent of color range to instrument reading (T.C.I.) of pink tomatoes. Color range, as indicated by identical symbol, shows color initially (starting at lower left), after 4-day holding, and when fully ripe (upper right). Broken lines indicate 95 percent confidence belt for solid regression line.

TABLE V.—*Effect of cooling and holding temperatures on color changes in pink tomatoes*

Holding temperature (° F.)	Visual color rating at indicated periods						
	At start of test		After 4-day holding period			After becoming red ripe at 70° F.	
	Color range	Average	Color range	Average	Change	Color range	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
60	30–40	33. 5	65–82	73. 9	120. 6	95–98	96. 6
55	35–45	40. 3	45–70	60. 3	49. 6	90–98	95. 6
50	40–50	43. 8	45–70	59. 3	35. 4	91–97	94. 9
60	15–25	18. 5	40–78	68. 1	268. 1	95–98	96. 8
55	20–30	25. 3	35–65	53. 0	109. 5	96–98	97. 2
50	20–30	24. 3	35–65	50. 5	107. 8	89–97	94. 5
60	10–15	11. 5	35–70	56. 0	387. 0	95–98	96. 3
55	10–15	12. 8	15–45	35. 2	175. 0	90–97	95. 5
50	10–15	12. 7	25–40	29. 3	130. 7	87–97	94. 3

EFFECT OF HOLDING TEMPERATURES ON CHILLING INJURY

Materials and Methods

Data on the effect of low but nonfreezing temperatures on pink tomatoes were accumulated during 1959, 1960, 1961, and 1964. Although the tests were primarily concerned with pink tomatoes, mature-green tomatoes were included to compare their susceptibility to chilling injury with that of pink tomatoes. Chilling injury was judged by the extent of alternaria rot (*Alternaria tenuis* auct.) occurring in the absence of obvious skin breaks and by failure of the fruits to color and ripen properly at 70° F. (*8*).

Test fruits of the Rutgers variety were grown at Beltsville, Md., each year except 1964. In 1964, Maryland-grown tomatoes of undetermined variety were purchased for the tests.

Procedures for harvesting and preparing test lots were the same as described previously. However, in these tests all color ratings were visual judgments. Two color ranges, 30 to 50 and 10 to 25 percent, were studied.

Control fruits of 30 to 50 and 10 to 25 percent color at the start of the tests were held at 70° F. for 8 to 10 and 10 to 12 days, respectively, until the fruits were fully ripe. Other similar test lots of each color range were delayed in ripening at 45°, 40°, and 32° for various periods and were then ripened at 70° for the same periods as indicated above.

In rating color, the control fruits held continuously at 70° F. were the first to be evaluated and the delayed lots were compared to the value assigned to the control fruits. The visual ratings are not accurate assessments of colors, but they are useful in evaluating obvious differences in color that are related to temperature treatments.

Results

During the holding periods the tomatoes continued to develop some color at 45° and 40° F., but there was practically no change at 32°. However, red developed rapidly in most fruits after they were shifted to 70°. The effect of various holding periods at 45°, 40°, and 32° on pink tomatoes prior to final ripening at 70° is shown in table 2.

Blotchy areas slow in changing from yellow to red during ripening appeared to be due primarily to sunburn. The extent of this condition varied from test to test. Although low temperatures intensified the delay in changing sunburned areas from yellow to red at 70° F., there was a strong tendency for affected fruits to recover the ability to develop red pigment.

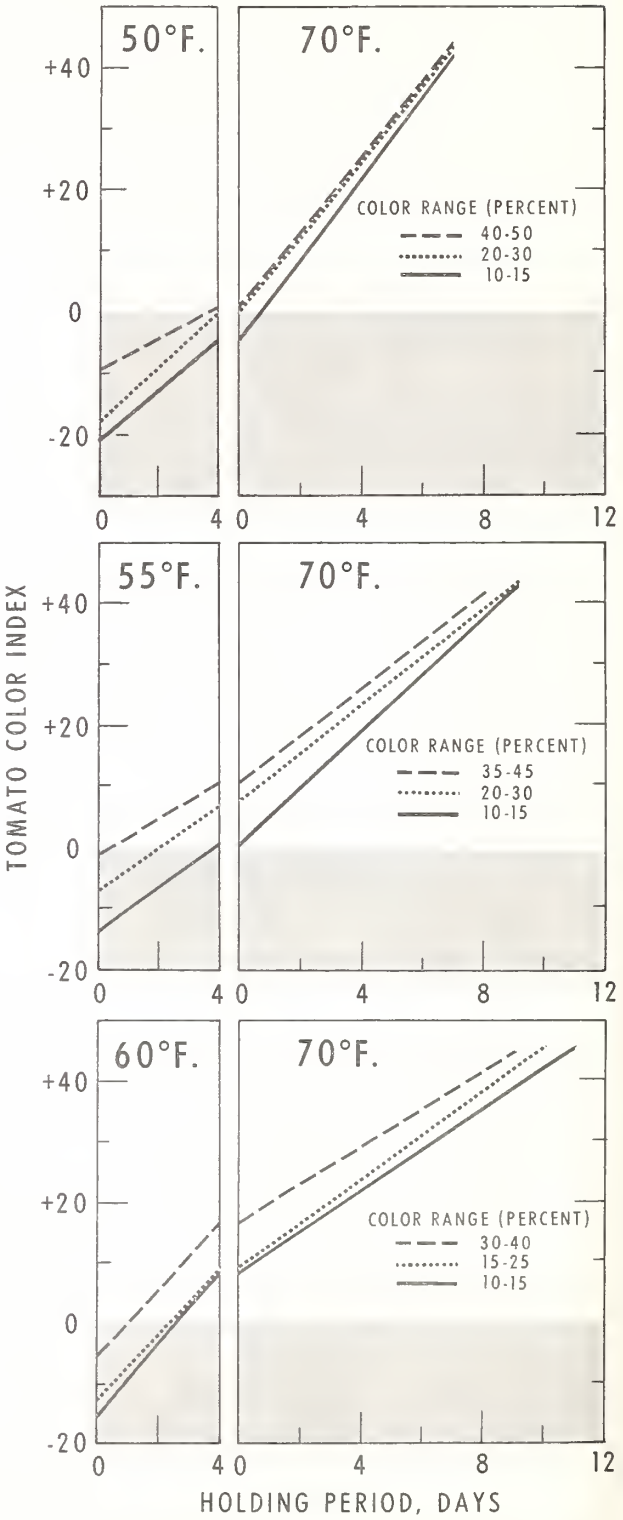

FIGURE 2.—Changes in color of pink tomatoes affected by cooling and holding temperatures (T.C.I. values expressed as mean of 6 readings on 20 fruits).

Fruits held at 45° and 40° F. for 2, 4, and 6 days were later ripened satisfactorily at 70° and had normal firmness. When finally ripe, these fruits were classified as being from 1 to 3 percent lower in red intensity than those held continuously at 70°. Alternaria rot was not a problem in these lots.

In addition to these treatments, tomatoes were also held at temperatures much lower than those recommended for tomatoes to insure the development of chilling injury. Similar lots of pink tomatoes were held at 32° F. for 6, 10, and 14 days and then held at 70° for 8 to 12 days to ripen. Companion lots of mature-green tomatoes harvested at the same time as the pink fruits were held at 32° for 6 and 14 days and then ripened at 70° in order to compare their susceptibility to chilling injury with that of pink tomatoes.

Holding tomatoes at 32° F. reduced their ability to form red color when they were transferred to 70° (table 2). However, the reduction in red intensity was only moderate for fruits held at 32° for 6 days. Ability to color was seriously damaged by holding fruits at 32° for 10 to 14 days. Fruits held at 32° were also less firm than those held at the higher temperatures.

Chilling injury of tomatoes held at 32° for 10 to 14 days was indicated by the extent of alter-

TABLE 2.—*Effect of holding temperature on subsequent color development, decay, and firmness of tomatoes in 3 color ranges at start of test*

Temperature (F.) and length of holding period (days)	Total fruits	Fruits sound	Condition of tomatoes when ripened at 70° F. after holding at lower temperatures				
			Color development of majority	Alternaria rot	Other rot	Total rot	Firmness
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
PINK TOMATOES WITH 30–50 PERCENT COLOR							
70°, continuously	174	98	95	0	2	2	Normal.
45°:							
2	92	99	94	0	1	1	Do.
4	95	97	93	0	3	3	Do.
6	94	94	93	1	5	6	Do.
40°:							
2	71	99	94	0	1	1	Do.
4	94	95	93	0	5	5	Do.
6	94	89	92	1	10	11	Do.
32°:							
6	152	87	88	2	11	13	Slightly lacking.
10	112	62	85	20	18	38	Moderately lacking.
14	153	21	80	42	37	79	Lacking.
PINK TOMATOES WITH 10–25 PERCENT COLOR							
70°, continuously	149	94	95	0	6	6	Normal.
45°:							
2	137	94	95	1	5	6	Do.
4	117	93	94	1	6	7	Do.
6	125	92	94	0	8	8	Do.
40°:							
2	61	95	93	0	5	5	Do.
4	82	91	93	0	9	9	Do.
6	82	89	92	0	11	11	Do.
32°:							
6	159	91	88	1	8	9	Slightly lacking.
10	104	63	84	19	18	37	Moderately lacking.
14	137	18	78	50	31	81	Lacking.
MATURE-GREEN TOMATOES							
70°, continuously	162	91	92	0	7	7	
32°:							
6	111	83	86	11	6	17	
14	141	15	56	82	7	89	

naria rot that developed at 70°. In addition to active lesions, these fruits showed numerous dark scars over the shoulder area from which *Alternaria tenuis* was isolated.

Fruit rots other than alternaria rot were mostly anthracnose (*Colletotrichum phomoides* (Sacc.) Chester). The extent of anthracnose varied from year to year. The organism in this locality attacks ripening fruits both before and after harvest, and the decay is usually increased by longer holding periods. However, anthracnose is not a problem on tomatoes in States where they are produced out of season for the fresh market. For this reason no emphasis was placed on anthracnose in this study.

The data indicate that mature-green tomatoes when grown, handled, and stored under the same conditions as pink fruits were more sensitive to low temperature than pink fruits, as indicated by the extent of alternaria rot.

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